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06/05/89
R. L. Garwin

Cold Nuclear Fusion (?)

CERN

1) First papers (U.U. & B.Y.U)
2) "Theory"
3) More recent results.
4) Conclusions
   (what to look for)

RC 14554 (#65131) 4/18/89
Physics 12 pages

Research Report

Electrochemical Experiments in Cold Nuclear Fusion

J. F. Ziegler, T. H. Zabel, J. J. Cuomo, V. A. Brusic,
G. S. Cargill III, E. J. O'Sullivan and A. D. Marwick

IBM Research Division
T.J. Watson Research Center
Yorktown Heights, N.Y. 10598

→ Phys. Rev. Lett.
04/18/89

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PREPRINT SUBMITTED TO: Europhysics Letters

EVIDENCE OF EMISSION OF NEUTRONS FROM A TITANIUM-DEUTERIUM SYSTEM

A. De Ninno, A. Frattolillo*, G. Lollobattista, L. Martinis, M. Martone*, L. Mori,
S. Podda*, F. Scaramuzzi

ENEA, Dip. TIB, U.S. Fisica Applicata, Centro Ricerche Energia Frascati,
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ARTICLES

Nature
04/27/89

Observation of cold nuclear fusion in condensed matter

S. E. Jones°, E. P. Palmer°, J. B. Czirr°, D. L. Decker°, G. L. Jensen°, J. M. Thorne°, S. F. Taylor° & J. Rafelski†

° Departments of Physics and Chemistry, Brigham Young University Provo, Utah 84602, USA
† Department of Physics, University of Arizona, Tucson, Arizona 85721, USA

When a current is passed through palladium or titanium electrodes immersed in an electrolyte of deuterated water and various metal salts, a small but significant flux of neutrons is detected. Fusion of deuterons within the metal lattice may be the

rate will be an upper limit; on the other hand, if fusion-produced ^3He is stored in the mantle (so that the outward flux does not equal the production rate), our value will be a lower limit. As each p-d fusion produces one ^3He atom, and as the isotopic abundance of deuterium in water is $\sim1.5\times10^{-4}$ deuterons per proton, we infer a geological fusion rate constant, λ_f, of

blätterfrage MARCHAND zu entsprechenden Feststellungen am Objekt, wie auch zu Ausführungen allgemeiner Natur veranlaßten (1899). Bei den Mißbildungen liegt das Interesse vor allen Dingen in der Art ihres Zustandekommens und auch hier griffen MARCHANDs Erklärungsversuche ... aus, indem sie die Ergebnisse ... Wirbeltieren und Wi... mentelle...

wie der Verlauf der nächsten beiden Jahrzehnte erwies.

Die wissenschaftliche Bet... MARCHAND alle...

Cold Fusion In Isotopic Hydrogen Molecules

S. E. Koonin * and M. Nauenberg **
Institute for Theoretical Physics
University of California
Santa Barbara, CA 93106

Submitted to *Nature*, April 7, 1989

1

Two Innocent Chemists Look at Cold Fusion

Cheves Walling* and Jack Simons*
Chemistry Department
University of Utah
Salt Lake City, Utah 84112

→ J. Chem. Phys

... daß sein Ver... Stellung für die weitere Au... der wissenschaftlichen Tätigkeit förderlicher sei und damit hat er wohl recht gehabt,

... stets das lebhaf... Lehrer, als Forscher, als Mensch ... MARCHAND zu den besten und edelsten. Heute seien ihm für seinen Lebensabend die herzlichsten Wünsche dargebracht; möge ihm seine Schaffensfreudigkeit auch fernerhin erhalten bleiben, denn arbeiten und der Wissenschaft dienen galt ihm stets als das höchste und so wird es bleiben bis ans Ende.

Über die Verwandlung von Wasserstoff in Helium[1]).

Von FRITZ PANETH und KURT PETERS, Berlin.
(Aus dem Chemischen Institut der Universität.)

Naturwissenschaften 1926

1. *Der Grundgedanke der Arbeit.*

In den modernen Fassungen der PROUTschen Hypothese, in den astro-physikalischen Berechnungen der Lebensdauer der Fixsterne und in den radioaktiven Überlegungen über den Ursprung der HESSschen Strahlung wird stets auf die theoretisch zu fordernde Verwandlungsmöglichkeit von Wasserstoff in Helium hingewiesen. Diese Elementverwandlung zu realisieren, ist aber bisher nicht gelungen, obwohl bereits mit den verschiedensten Arten elektrischer Entladungen unter Zufuhr großer Energiemengen daran gearbeitet worden ist.

Nun ist die Reaktion selber vermutlich in höchstem Maße energieliefernd; aus der Massenabnahme der 4 Grammatome Wasserstoff beim Übergang in Helium berechnet sich eine Wärmetönung von $6{,}4 \times 10^{11}$ cal. Es ist daher gar nicht sicher, daß überhaupt Energie zugeführt werden muß, um die Reaktion zum Ablauf zu bringen. Eine andere Möglichkeit, die Reaktion nachweisbar zu machen, könnte darin bestehen, daß man die an und für sich unmeßbar langsam verlaufende Elementverwandlung katalytisch beschleunigt. Der Grundgedanke unserer Arbeit war daher, zu prüfen, ob sich *Wasserstoff ohne Energiezufuhr*

[1]) Berichte der Deutschen Chemischen Gesellschaft Jg. 59, Nr. 8, S. 2039. Die Erlaubnis zum Abdruck der Arbeit haben Die Naturwissenschaften dem Vorstande der Deutschen Chemischen Gesellschaft und der Schriftleitung der Berichte zu danken.

Also see Nature 1927 etc

teilweise in ... einem gee... und zwar ... *Palladium* ... Über di... während ei... im günstigs... fehlte natür... die Aussich... um so bess... *Nachweisme*... Der Versuc... mußte also ... die Grenze ... zudrücken, ... selbe Größe ... erreichbar s... natürlich g... heute, nach ... sem Proble... und wollen ... Eine ausfü... der Appara... an anderer ...

2. ...

Durch ... Verfahren ... suchung ha... auf 10^{-8} b... 10^{-13} g) hin... wir zunächs... lativ leicht ... siger Luft g... Wasserstoff ... Wasser vere... nicht, wie ... Entladunge... Platin- oder ... Sauerstoff ... Kohle entfe... Glascapillar... die außen ... bei ihrer Fei... Spektroskop... schilderten ... bleibenden ... ginn der d... dungen in ... Wasserstoff, ... Gasen, vor... stand für de... liegt nun d... regung in d... früher vers... Helium und ...

Eine En... Verfahren ... auszuführen ... deren Meth...

[1]) Etwa ... Glas (siehe ...

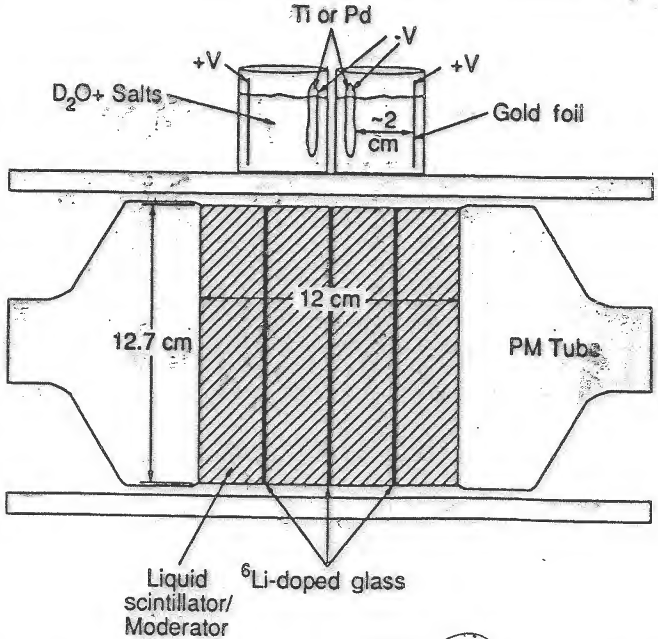

FIG. 1 Schematic diagram of the experiment. Electrolytic cells are shown on top of the neutron spectrometer.

BYU

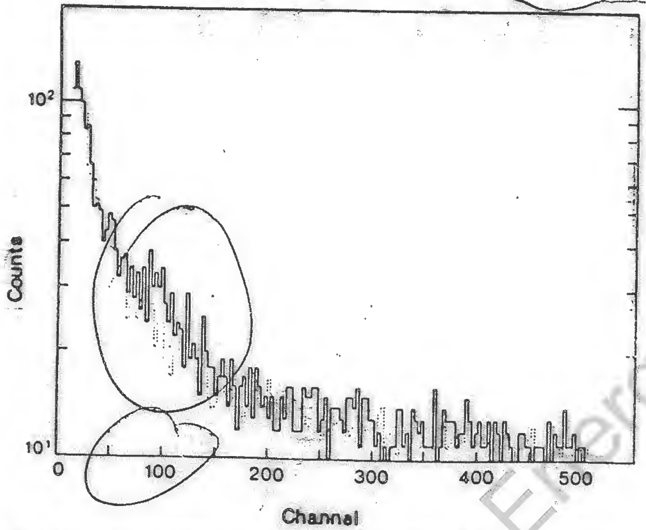

FIG. 2 Foreground (solid) and background (dashed) counts as a function of pulse height (corresponding to neutron energy) in the neutron spectrometer. Ten counts have been added to each three-channel bin for clarity of presentation.

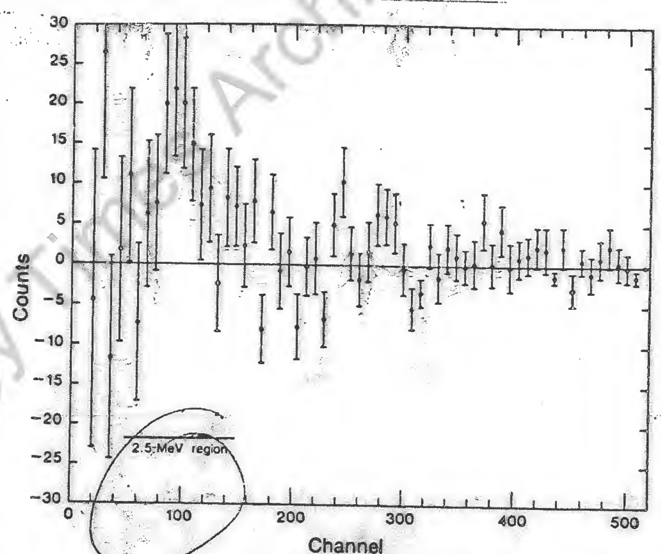

FIG. 3 Difference spectrum obtained by substracting scaled background from the foreground. Statistical errors ($\pm 1\sigma$) are shown for each eight-channel bin.

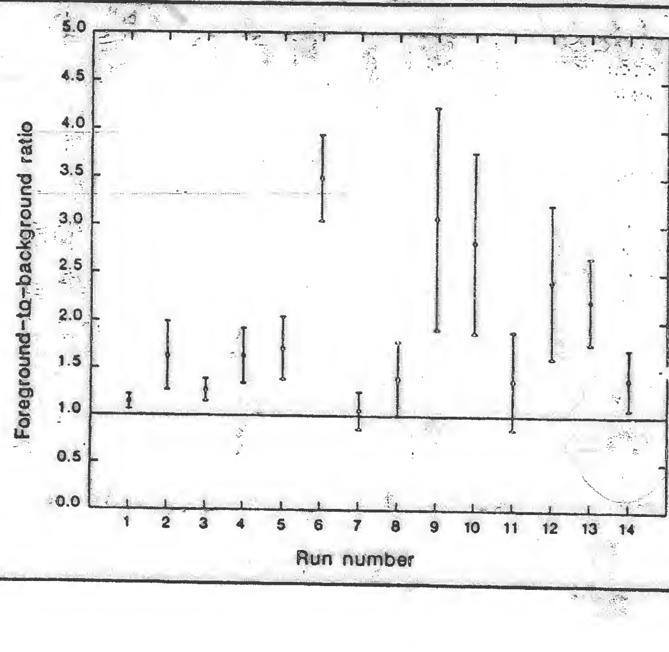

FIG. 4 Ratio of foreground rate to background rate for each run, in the 2.5-MeV energy region of the pulse-height spectrum. Statistical errors ($\pm 1\sigma$) are shown.

Date: Tue, 9 May 89 12:03:56 PDT
From: koonin@sbitp.bitnet
Message-Id: <890509120356.3be@sbitp.ucsb.edu>
Subject: report on the ecs meeting
To: perry@ohstpy.bitnet, feng@duvm.bitnet, rlg2@yktvmt.bitnet
X-ST-Vmsmail-To: ST%"perry@ohstpy.bitnet", ST%"feng@duvm.bitnet",
ST%"rlg2@yktvmt.bitnet"

May 9, 1989
11:30 PDT

There follows an eyewitness report on the speical session on Electrochemically Induced Cold Fusion sponsored by The Electrochemical Society last night in Los Angeles. There were about 2000 people in attendance at the Bonaventure Hotel. No cameras or recording devices were allowed in the hall, so what follows is a somewhat subjective and incomplete report based on my notes. I will also restrict my report to what I consider new information that was presented.

PROGRAM:

The scientific program of the meeting was:

--"Electrochemically-Induced Nuclear Fusion of Deuterium" (S. Pons and M. Fleischmann) 40 min.

--"Observation of Cold Nuclear Fusion in Condensed Matter" (S. E. Jones et al.) 25 min.

--"Thermal measurements of D-Pd and H-Pd Systems" (R. A. Huggins et al., Stanford) 15 min.

--"Observations of Heat Generation, Increased Tritium Concentration, and Enhanced Neutron Count in the Electrolysis of Deuterium Oxicde on Palladium Cathodes' (U. Landau et al., Case Western Reserve) 10 min.

--"Mass Spectrometric Detection of Hydrogenic Species during Electrolysis of D2O at a Palladium Cathode" (E. Struve et al., University of Washington) 10 min.

--"Electrochemically-induced Fusion of Deuterium: The Search for Neutrons and Fusion Products" (J. Jorne et al., University of Rochester) 10 min.

--"Evidence for Excess Heat Generation During Electrolysis of D2O (Pd Cathode/ Pt Anode) in LiOD - A microcalorimetric Investigation" (S. Srinivasan et al., Texas A&M) 10 min.

--"The Fleischmann-Pons Effect: Facts and Theory at an Early Stage of Investigation" (J. Bockris et al., Texas A&M) 10 min.

--"Calorimetry, Neutron Flux, Gamma Flux, and Tritium Yield from Electrochemically Charged Palladium in D2O" (N. Lewis et al., Caltech) 10 min.

These talks were followed by about an hour of questions from the audience to all of the speakers. The (by now obligatory) press conference followed.

PONS and FLEISCHMANN:

The most surprising part of the Pons-Fleischmann presentation was how little things had changed. It was basically a rehash of the same material we've been

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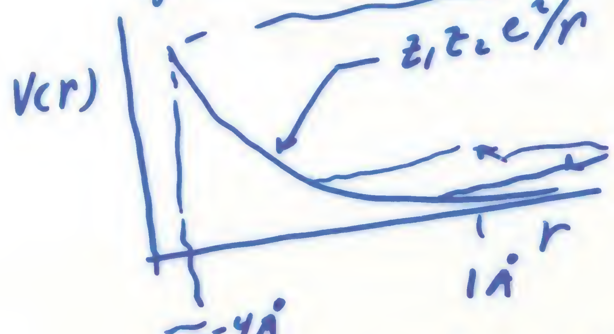
Quantum tunneling to fusion: 600 keV



$$\psi^2(0) \propto e^{-2\int_{r_0}^{0} k(r)\,dr} \qquad \mu \equiv \frac{M_1 M_2}{M_1 + M_2}$$

$$k = \frac{2\pi}{h}\sqrt{2\mu[V(r) - E]}$$

D+D → He^3 + n + 3.27 MeV

→ H^3 + p + 4.03 MeV

$\log_{10}$ fusion rate per particle per second in "hydrogen" molecule bound by m^*

(e.g. Koonin & Nauenberg 1989)

m^*/m_e	1	2	5	10
λ_{dd}	−63.5	−40.4	−19.8	−9.1
$\lambda_{p\text{-}d}$	−55.0	−36.0	−19.0	−10.4

Walling: m^* would also enhance "internal conversion" rate (IC)

So He^4(23.8 MeV*) → He^4 + γ (23.8 MeV)

→ He^4 + e^- (23.8 MeV) [I

Even if $\lambda_{IC} = 10^9\ s^{-1}$, $\lambda_{(He^3+n)(H^3+p)} \sim v_n/r_n \sim \frac{10^9\ \text{cm/s}}{10^{-12}\ \text{cm}}$

$\sim 10^{21}\ s^{-1}$

(b) (a)

[for a "width" of 1 eV, $\Delta E \Delta t = \hbar$ → $\Delta t = \frac{10^{-27}}{1.6\times10^{-12}} = 0.6\times10^{-15}$ s

∴ 20 keV ΔE

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Why "Even if"?

Heavy electrons (m^*) in solid. (simple view)

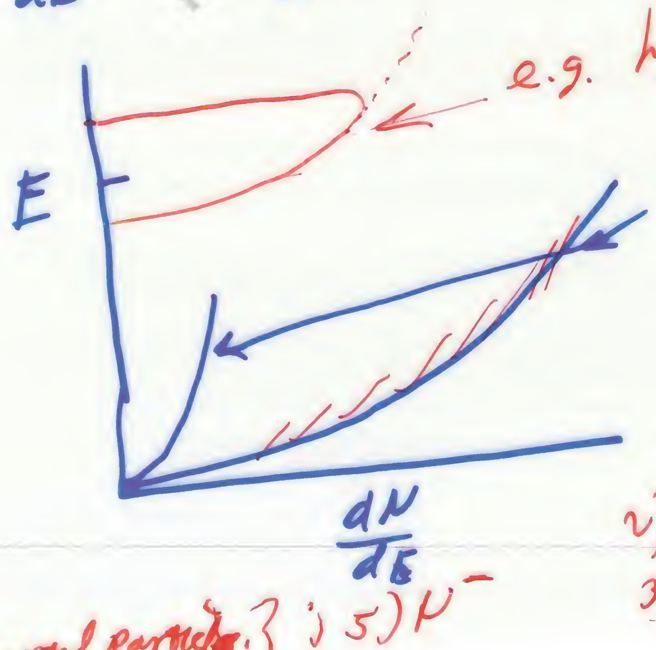
number of quantum states per unit volume with $k \leq k_{max}$ $\quad N \simeq 2 \times \frac{4\pi}{3} k_{max}^3$

but $\hbar k = p$ and $E \simeq \frac{p^2}{2m^*} \simeq \frac{\hbar^2 k^2}{2m^*}$

$$N \simeq k_m^3 \simeq \left(\frac{2m^* E}{\hbar^2}\right)^{3/2} \simeq \frac{m^{*3/2}}{\hbar^3} E^{3/2}$$

$$\frac{dN}{dE} \simeq \frac{(m^*)^{3/2}}{\hbar^3} E^{1/2} \quad \text{or} \quad E \propto \left(\frac{dN}{dE}\right)^2 \times \frac{1}{(m^*)^3}$$

e.g. hydrogen atoms on a lattice.



$m^* = 1$ (free e^- in a box)

D + Li

1) Verdict:

2) $[T_{cell} - T_{bath}] \times K_{cell} = \text{Watts}$

3) $He^4/D_2 = \frac{3\,eV}{24\,MeV} \leq 0.1\ \text{ppm}$

4) charged particles? ; 5) N^-

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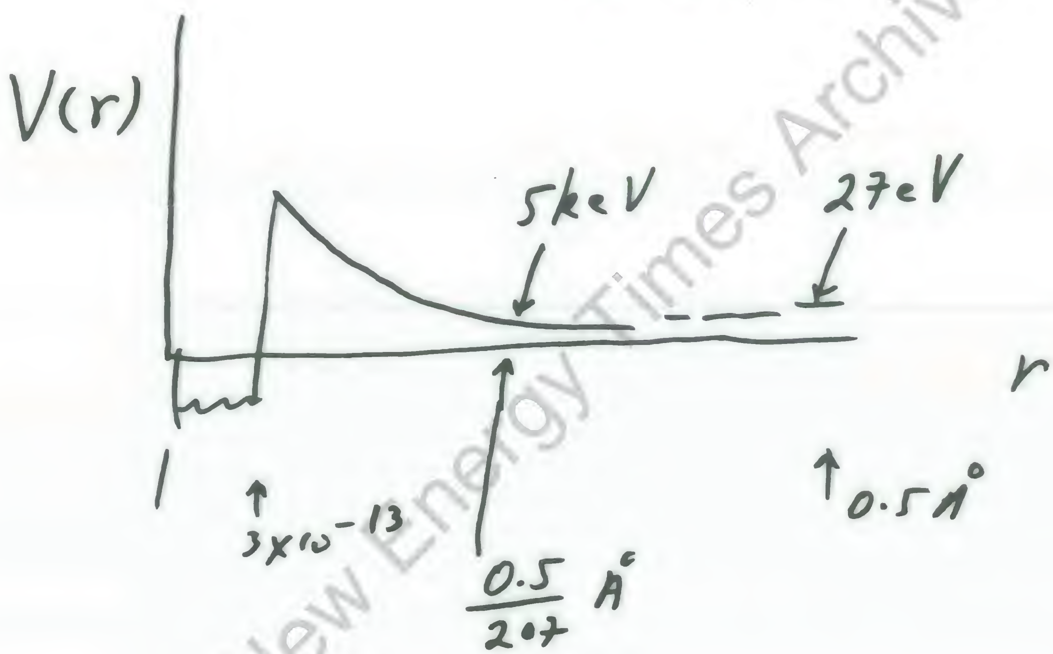
(1)

Cold fusion

$$D + D \to He^3 + n \quad \} \; 50:50$$
$$\quad\;\; \to T + p$$

Coulomb barrier $V = \frac{e^2}{r}$ at $r = 2 \times 1.5 \times 10^{-13}$ cm

$= 500$ keV



- accelerator beams 10 MeV – 1 MeV – 10 keV
- thermal fusion -- ICF, H-bombs 1 keV – 100 keV (T)
- tunneling -- ", μ^--catalyzed fusion,

  Cold fusion?

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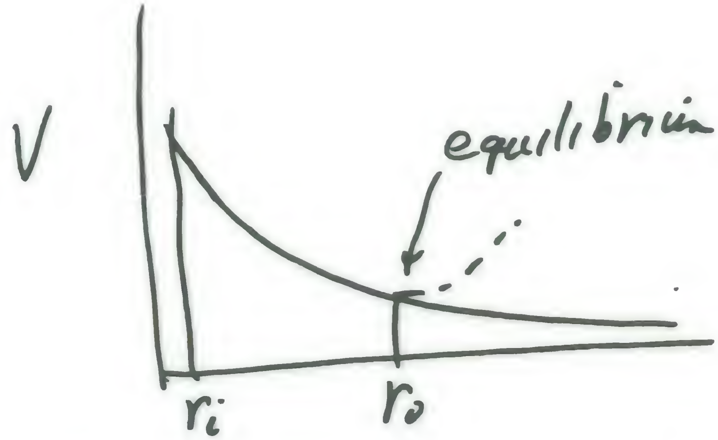
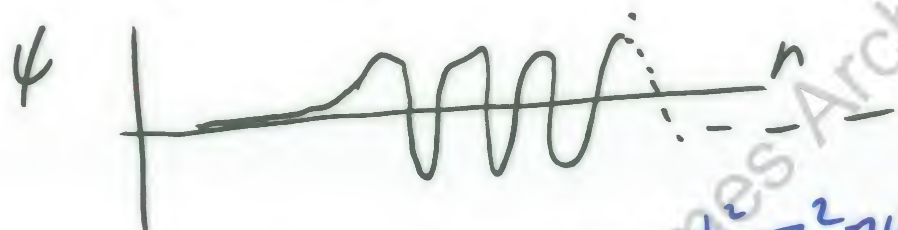
(2)





$$T + V = E \quad ; \; -\frac{\hbar^2}{2m}\nabla^2 \Psi = (E-V)\Psi$$

$$\psi \equiv 4\pi r \Psi$$

$$-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + (V-E)\psi = 0$$

(~~should use~~ $r\psi$)

let $\psi = \cancel{e^{i\varphi}}\, e^{\varphi}$

$$e^{\varphi}\varphi'' + e^{\varphi}\varphi'^2 + \frac{2m}{\hbar^2}[E - V(x)]e^{\varphi} = 0$$

$$\varphi'' + \varphi'^2 + \frac{2m}{\hbar^2}[E - V(x)] = 0$$

approx:

$$\varphi' = \sqrt{\frac{2 m_r e^2}{\hbar^2}\left(\frac{1}{r} - \frac{1}{r_0}\right)}$$

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(3)

$$\varphi' = \left(\frac{2 m_r e^2}{\hbar^2}\right)^{1/2} \left(\frac{1}{r} - \frac{1}{r_0}\right)^{1/2}$$

$$= \left(\frac{2 \times 1.6\times10^{-24} \times 25\times10^{-20}}{10^{-54}}\right)^{1/2} (\quad)^{1/2}$$

$$= \quad 9\times10^{5} \quad (\quad)^{1/2}$$

If $r \equiv 10^{-8} R$ $\quad$ (R in Å)

$$\varphi' = 0.9\times10^{10}\left(\frac{1}{R} - \frac{1}{R_0}\right)^{1/2}$$

$$\varphi = -0.9\times10^{10}\int_{\cancel{R}=R_0}^{\cancel{R}=R} \left(\frac{1}{\cancel{R}\,X} - \frac{1}{\cancel{R_0}\,X_0}\right)^{1/2} dX$$

let $y \equiv 1/x$, $\quad \varphi = +0.9\times10^{10}\displaystyle\int_{y=\frac{1}{R_0}}^{y=1/R} (y-y_0)^{1/2}\,\frac{dy}{y^2}$

#171 & #167:

$$Y \equiv a + by + cy^2$$

$$\int \equiv -\frac{(y-y_0)^{1/2}}{y} - \left(\tfrac{1}{2} y_0^{1/2}\right) \sin^{-1}\left(\frac{y-2y_0}{y}\right)$$

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(4)

for $y = y_0$, $\int = \dfrac{\pi}{4 y_0^{1/2}}$

for ~~y=~~ $y = \infty$ $(x=0)$, $\int = -\dfrac{\pi}{4 y_0^{1/2}} - \dfrac{1}{y_0^{1/2}}$

for $y = 2y_0$, $\int = \dfrac{-1}{2 y_0^{1/2}}$

Definite integral $\Big|_{y_0}^{y}$ for $y = \infty \rightarrow \dfrac{2.57}{y_0^{1/2}}$

for $y = 2y_0 \rightarrow \dfrac{1.38}{y_0^{1/2}}$

E.g., take $x = X_0/2$; $y = 2y_0$

$$\varphi = -\frac{0.9 \times 10^{10}}{10^8} \times \frac{1.38}{y_0^{1/2}} = -124\, X_0^{1/2}$$

$\varphi = -231 \cdot X_0^{1/2}$. for $X_0 = \dfrac{0.5}{207} = 2.5 \times 10^{-3}$, $X_0^{1/2}$ 0.0

$\varphi = -10.6$ ~~4~~ $24 \rightarrow$ ~~10~~ $e^{24} = e^{-21}$

To lose reaction rate of $10^{33} \rightarrow e^{76}$ we need $\varphi \rightarrow \varphi_0 - 38$

$\varphi \rightarrow -49$, $X_0^{1/2} = 0.21$; $X_0 = \underline{\underline{0.04}}\,\text{Å}$

"$^{1}H + n(2.45\,MeV) = {}^{2}D + \gamma(2.5\,MeV)$"

(vii)

1) $^{1}H + n\,(0\ energy) \rightarrow {}^{2}D + \gamma(2.2\,MeV)$ ✓

2) $(2.45\,MeV)$ would go to $\gamma(4.65\,MeV)$ (if at all).

3) But neutron <u>moderates</u> by elastic collision with protons in water.

$10\ W/cm^3 \times 100$ hours $\times$ $(3.6 \times 10^5 s) \times 10 = 4 MJ/cm^3$

4') $4\ MJ/cm^3$ is $\dfrac{4 \times 10^6 \times 10^7 \text{ erg}}{5 \times 10^{22}}$

$= 0.8 \times 10^{-9}$ erg/particle (Pd or D)

$1\ eV = 1.6 \times 10^{-12}$ erg, so

$4 MJ/cm^3$ is 500 eV per D.

Chemical energies $\leq$ 3 eV per particle

— At ~10 MeV per fusion,

500 eV/D is $\dfrac{5 \times 10^2}{10^7} = 5 \times 10^{-5}$ f/D --

-- — so product should readily be seen.

$10\ W/cm^3$ is 6×10^{13} MeV/cm^3 sec

$\left.\begin{array}{l} \sim \underline{6 \times 10^{12} \text{ fusions/cm}^3 \text{ sec}} \\ \text{vs } 4000\ \gamma/\text{sec} \end{array}\right\}$ F-P

— Can't be D-D or even P-D.

If $D + Li^6$ were possible $\rightarrow Be^8 \rightarrow \underline{He^4 + He^4}$ 22.4 MeV

$p + Li^7$ would be much faster. 17.3 MeV

No mechanism known to permit this.

$p + Li^6 \rightarrow He^4 (1.7 MeV) + He^3 (2.3 MeV)$ $He^3 + d \rightarrow He^4 + p$.

04/12/89

Questions provoked by experiments:

BYU - (1) Are neutrons generated by the electrolysis? [Crucial question]

(1.1) If so, how reproduce & optimize?

(1.2) Why not vast amount of data since 03/23/89?

U.U. --

(2) Gamma rays.

(2.1) Display full spectrum -- escape peaks, etc.;

(2.2) Claim: "spectrum confirms that 2.45 MeV neutrons are indeed generated"! — X
- no such reaction; no such energy of γ.

(2.3) gammas associated with heat?

-[How to do xpt.]

(3) neutrons — when?

(4) heat --

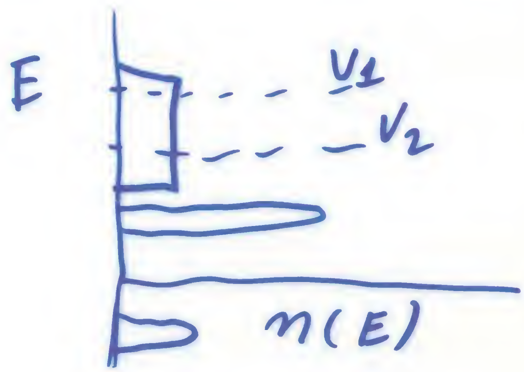
(4.1) Explosive release. Why not chemical?

(4.2) steady release -- run-by-run details, other sources -- e.g. D_2 + air ?? why not stir?

04/12/89 (4)

U.U.I

What is disruptive pressure in PdH_x?



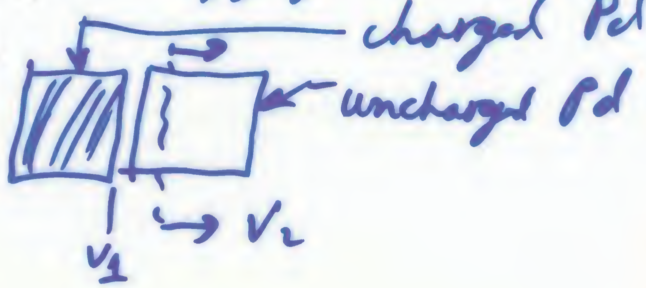
Notional density of states vs. energy of sites.

a) Electrolyze to charge sites with D.

["diffusion time"]

b) Cut off electrical supply.

$\Delta E = P \Delta V$



So $P \sim E \cdot n$

$\sim \underset{1.6\times10^{-12}}{1\,eV} \cdot 5\times10^{22}$ atoms/cm^3

$= 8\times10^{10} = \underline{80{,}000 \text{ atm}}$

So:

04/12/89 (2)

U.U (cont).

(5) Tritium.

Quantity in D_2O feed? 100 dpm/ml measured

– Data from J. Bigeleisen

-- 100 – 200 dpm/ml in D_2O.

-- "P-D separation factor 9.5".

(6) How negate "arcs and sparks" hypothesis?

(7) ~~Corroborate~~ Lend "charged" cathodes to other Labs?

Cold Nuclear Fusion

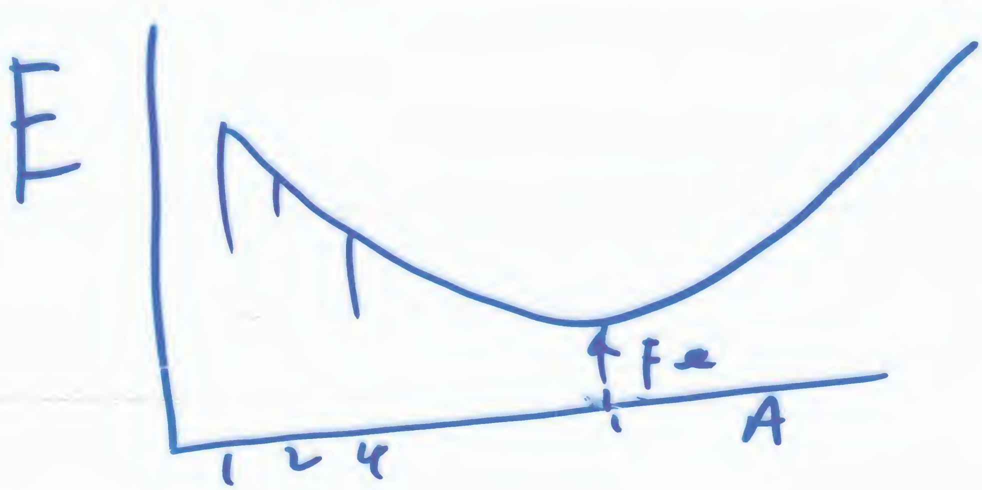
05/09/89

03/23/89 -- U.U. { Pons, S.
Fleischmann, M.
Hawkins, M.

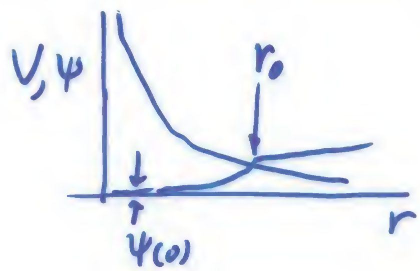
-- BYU { Jones, S.E.
Palmer, E.P.; Czirr, J.B.;
Decker, D.L.; Jensen, G.L.;
Thorne, J.M.; Taylor, S.F.;
Rafelski, J.

BYU -- 170 counts ± 23

UU -- - Heat! ~ 1 watt
- neutrons (gammas ~) ~ $10^3 s^{-1}$
- tritium (^3H) ~ 100 dpm/ml
- ^4He ~ $10^{12} s^{-1}$



04/11/89



$$\frac{\psi(0)}{\psi(r_0)} = e^{-\varphi} \qquad \varphi \propto m_r^{1/2}$$

for D-D, $m_r = 1$ a.m.u. ; $\varphi = 231\ r_0^{1/2}$ (r_0 in Å)

P-D, $m_r = 2/3$ a.m.u. ; $\varphi = 189\ r_0^{1/2}$

D-Dμ, $m_r \sim 1$ a.m.u. ; $r_0 = \frac{0.74}{200}$; $\varphi = 14$. rate $\sim 10^6\ s^{-1}$

By comparison with D-Dμ, D-De

is slower by $e^{(2\varphi(r_0^{1/2}) - 2\varphi_\mu)} = e^{462 r_0^{1/2} - 28}$

for this rate to be $10^{-23}\ sec^{-1}$ (10^{29} times slower than D-Dμ)

the exponential must be $e^{29 \times 2.303} = e^{67}$ larger

so that $462\, r_0^{1/2} = 28 + 67$; $r_0^{1/2} = 0.205$; $r_0 = 0.04$ Å

thus $m^*/m_e = \frac{0.74}{0.04} = \underline{\underline{18.5}}$.

If we are seeing something like P-D, $r_0 \sim 0.0625$

$\frac{m^*}{m_e} = \underline{12}$.

05/12/89

Cold nuclear fusion

NSB mtg.
(R.L. Garwin)

the creation -- 03/23/89

U.U.
BYU
(but)

press Conferences + mtgs:

04/12/89 Erice (Sicily)
05/01-02/89 APS (Baltimore)
05/08/89 El. chem. Soc. (Los Angeles)

the Nay-sayers / finders.

the once-confirmers.

the maintainers

Congressional response

DOE response

Comments on communications

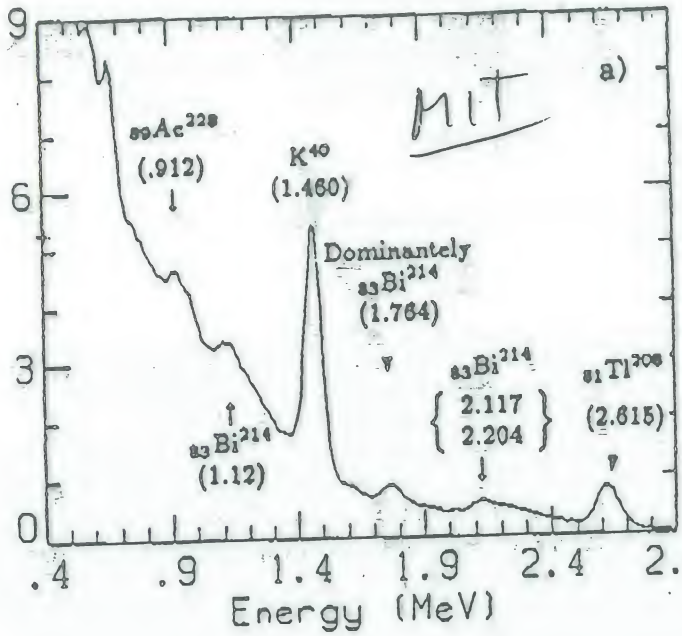
05/12/89

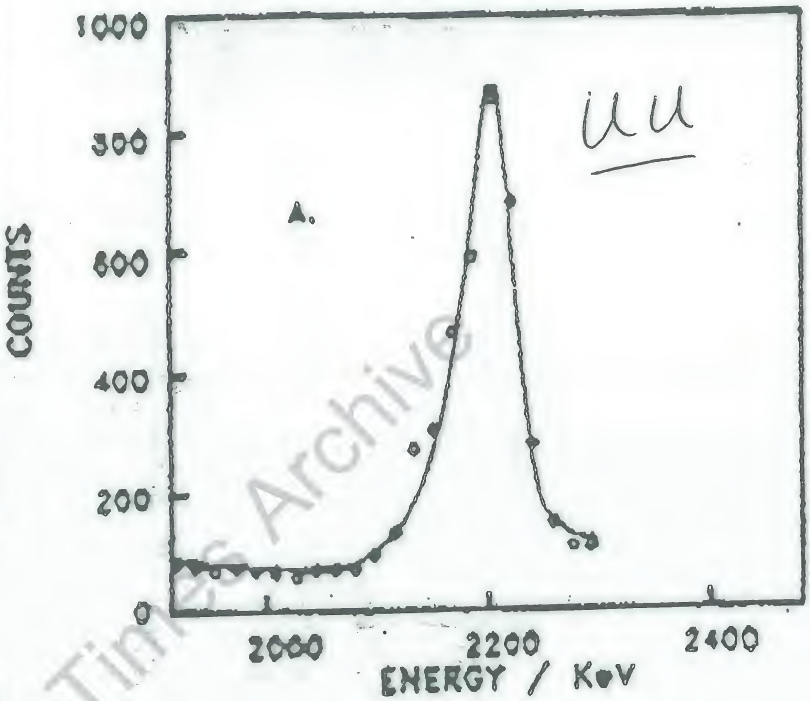
Texas A&M reported 05/08:

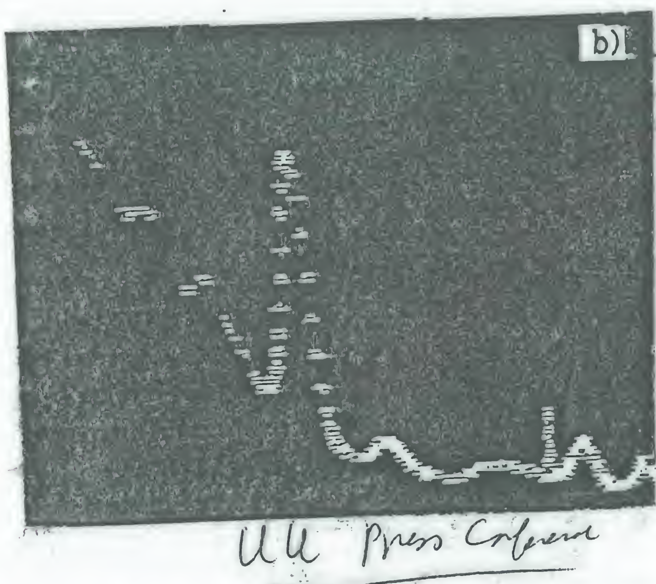
1) S. Srinivasan, et al. Microcolorimetry 10^{-6} - 8 W.
Pd rods 0.5 mm & 1 mm diam x 10 mm long.
also 2-mm diam sphere
~1/3 of 20 cells show "excess heat"
Best 30 mW (10% more than power in)

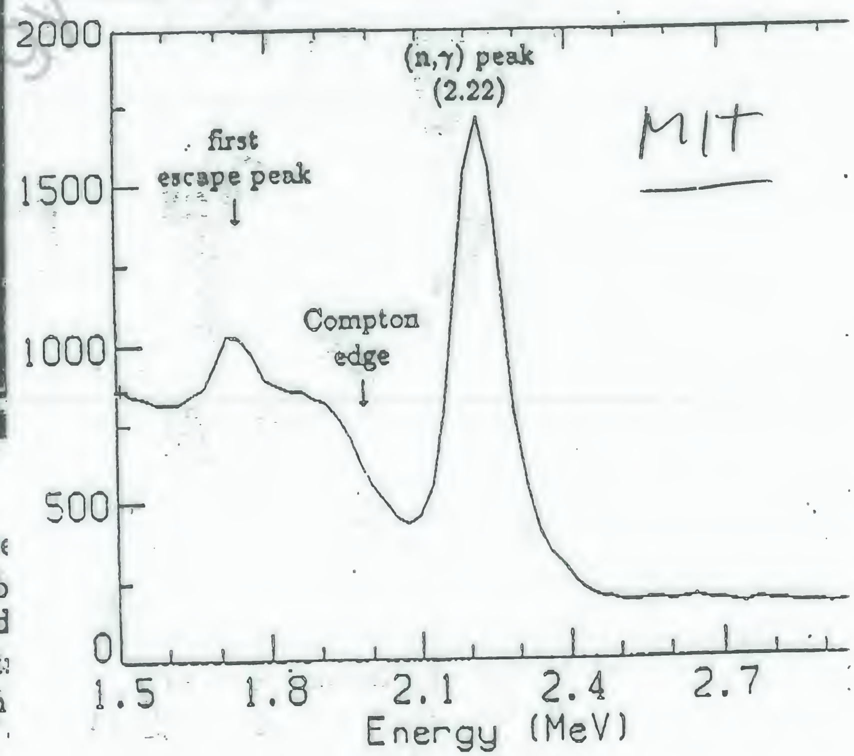
2) John Bockris reporting on Kevin Wolf.
2/20 cells were "live" -- one reproducible
Some neutrons seen in S.C.
≤ 50 n/min.
Tritium detected
"60-80 dpm/ml in D_2O
→ 10^6 dpm/ml after a few hours"

3) Nate Lewis, Caltech









omparison of the γ-ray background spectrum me
op) and the γ-ray spectrum shown on television b
ottom). a) The background spectrum measured
aI(Tℓ) detector at MIT. Some important terrest
ave been identified in this figure. The spectrum
n 84-hour run. b) The γ-ray spectrum of FPH[2].
haracteristics of the two spectra are similar; one
he two detectors have comparable spectral resol
b, note the curious structure at about 2.5 MeV a
ℓ^{208} peak (2.61 MeV), which appear to be artifac
pectrum can be obtained from KSL-TV in Utah.[1]

γ-ray spectrum measured by a 3" x 3" NaI(Tℓ) spectr
a neutron-capture-on-hydrogen experiment, which ut
(PuBe) neutron source submerged in water. Beca
size of the crystal (which is identical to that of FPH (

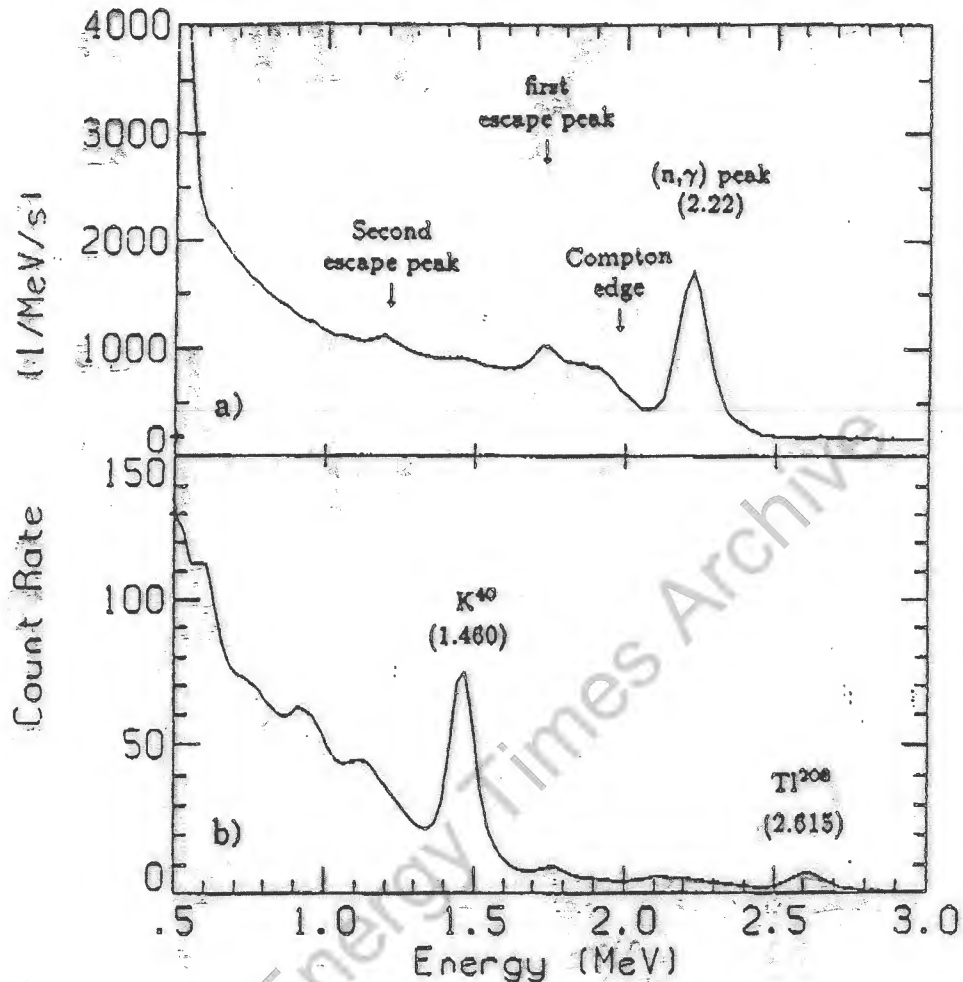


Fig. 4 The full γ-ray spectrum measured at MIT in a neutron-capture-on-hydrogen experiment, which utilized a (PuBe) neutron source submerged in water. a) The γ-ray spectrum due to (n, γ) reaction. One can see the single and double pair escape peaks, and of particular importance to this paper, the Compton edge. b) The γ-ray background measured with the same experimental setup and at the same location during a 24-hour period prior to the neutron experiment. The vertical scale in the figure is in counts per 100 minutes. See Citation 5 for the experimental arrangement.

PFC/JA-89-24

γ-Ray Spectra in the Fleischmann, Pons, Hawkins Experiment

R. D. Petrasso, X. Chen, K. W. Wenzel,
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(617) #0253-5553

April 1989 → Nature

Electrochemically Induced Nuclear Fusion of Deuterium

Eq viii on p 3.5 ??
8.4 ??

Fig 2 ??
8.3 [illegible]

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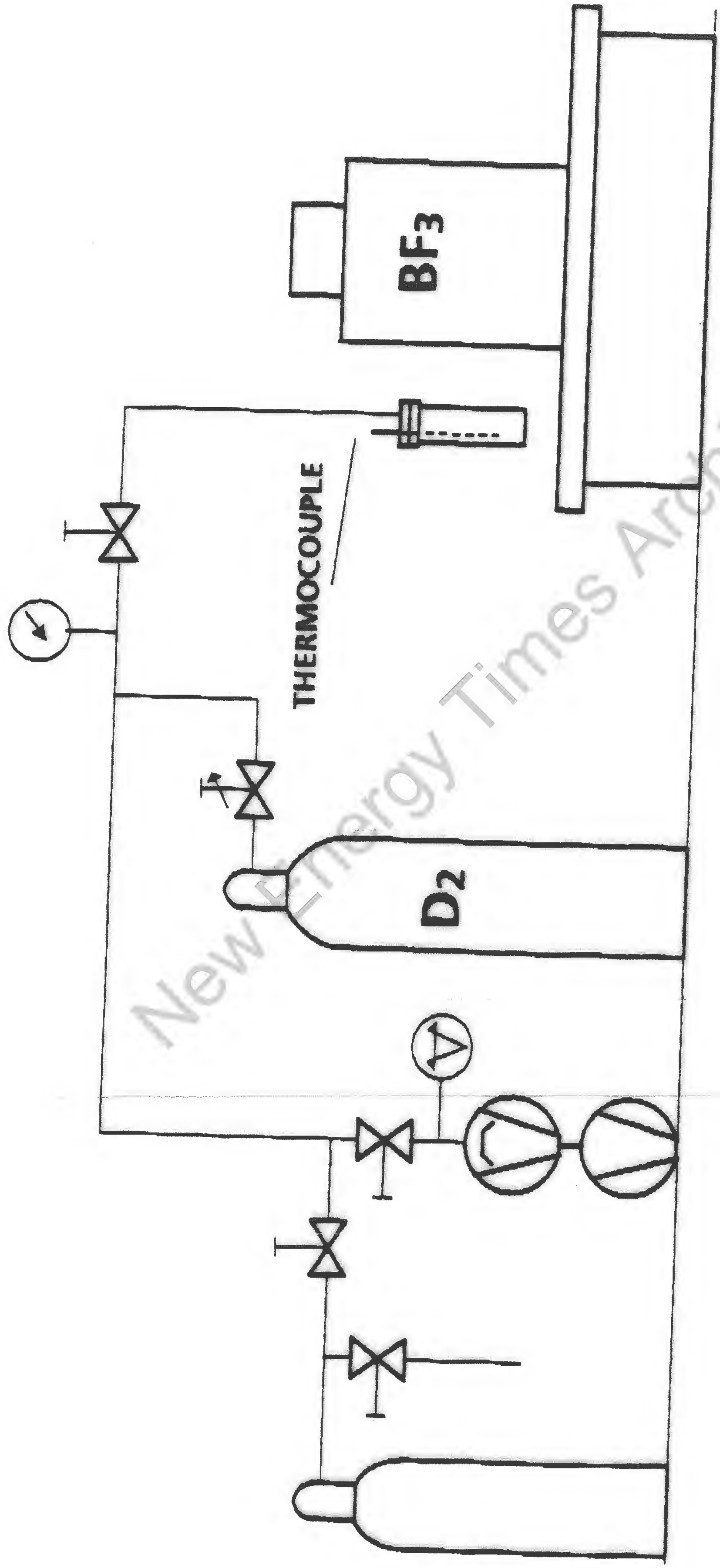
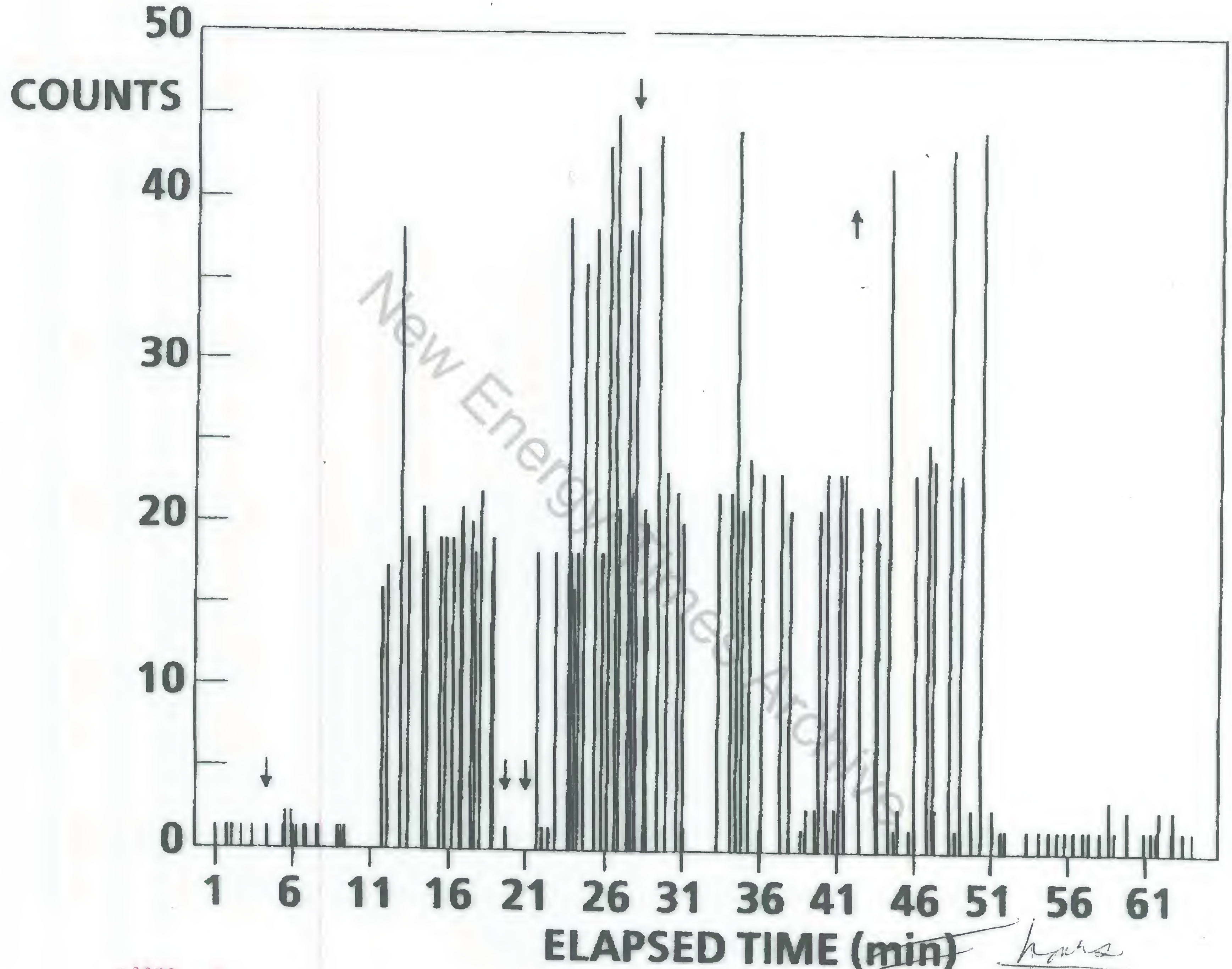
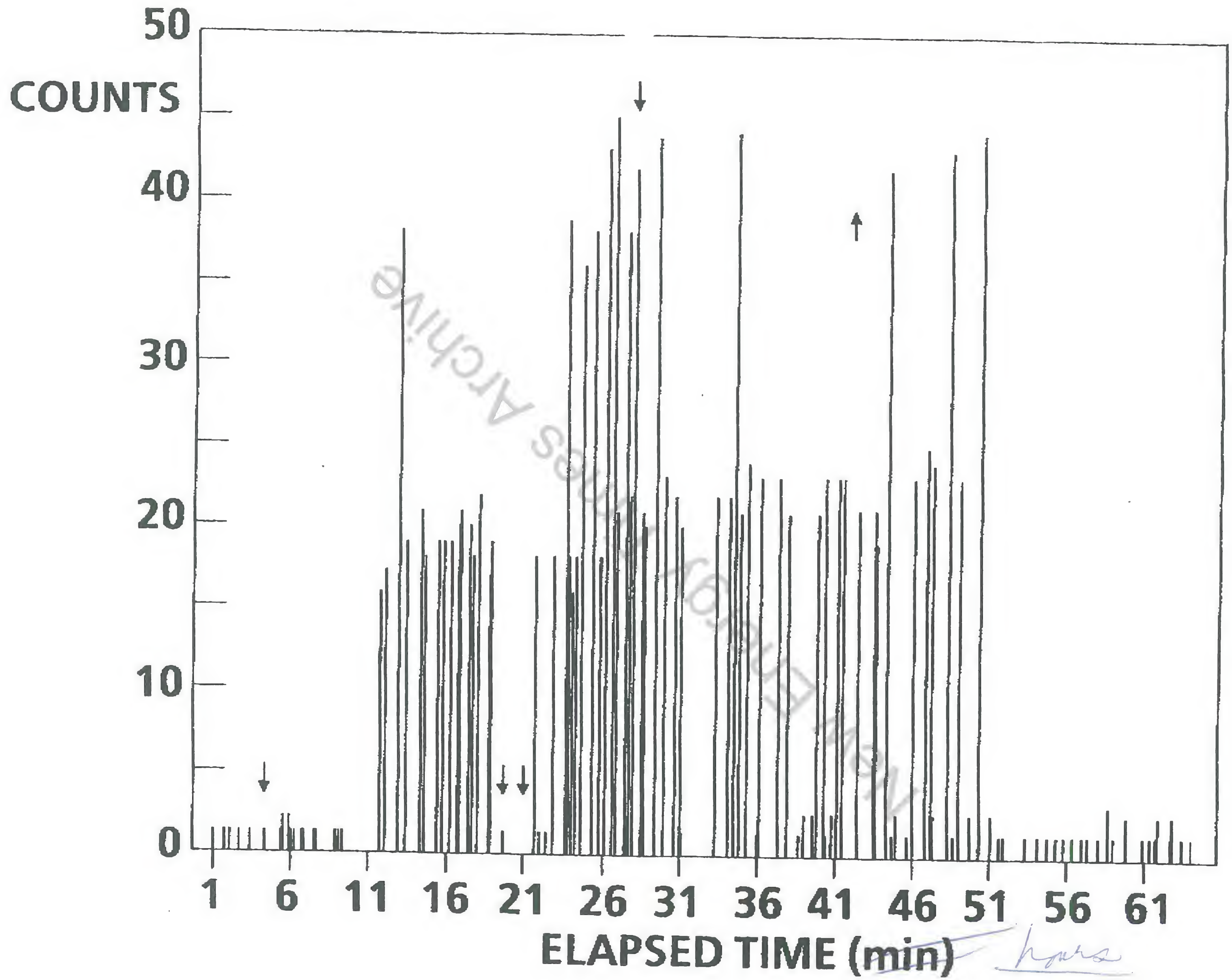
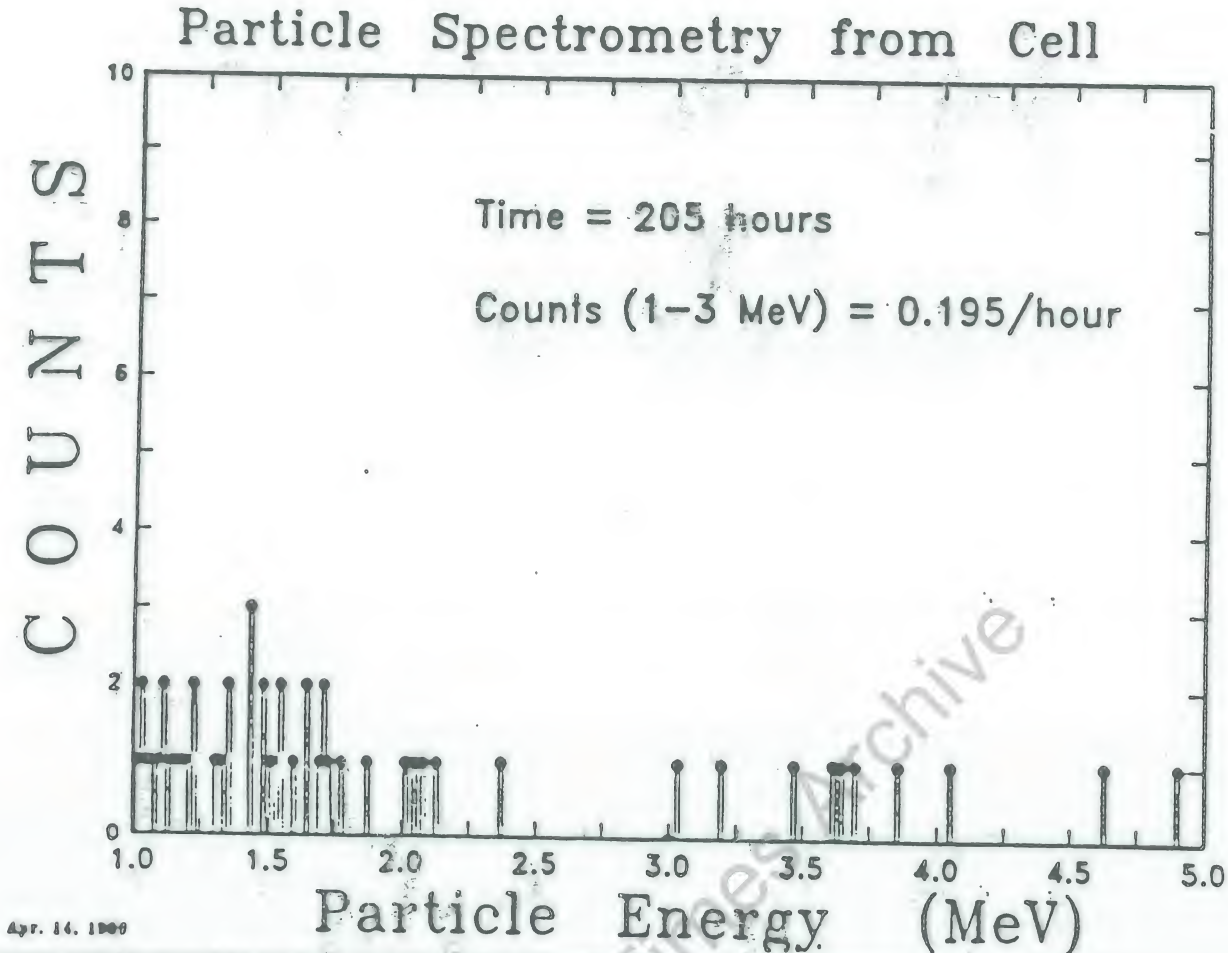

BF_3
THERMOCOUPLE
D_2

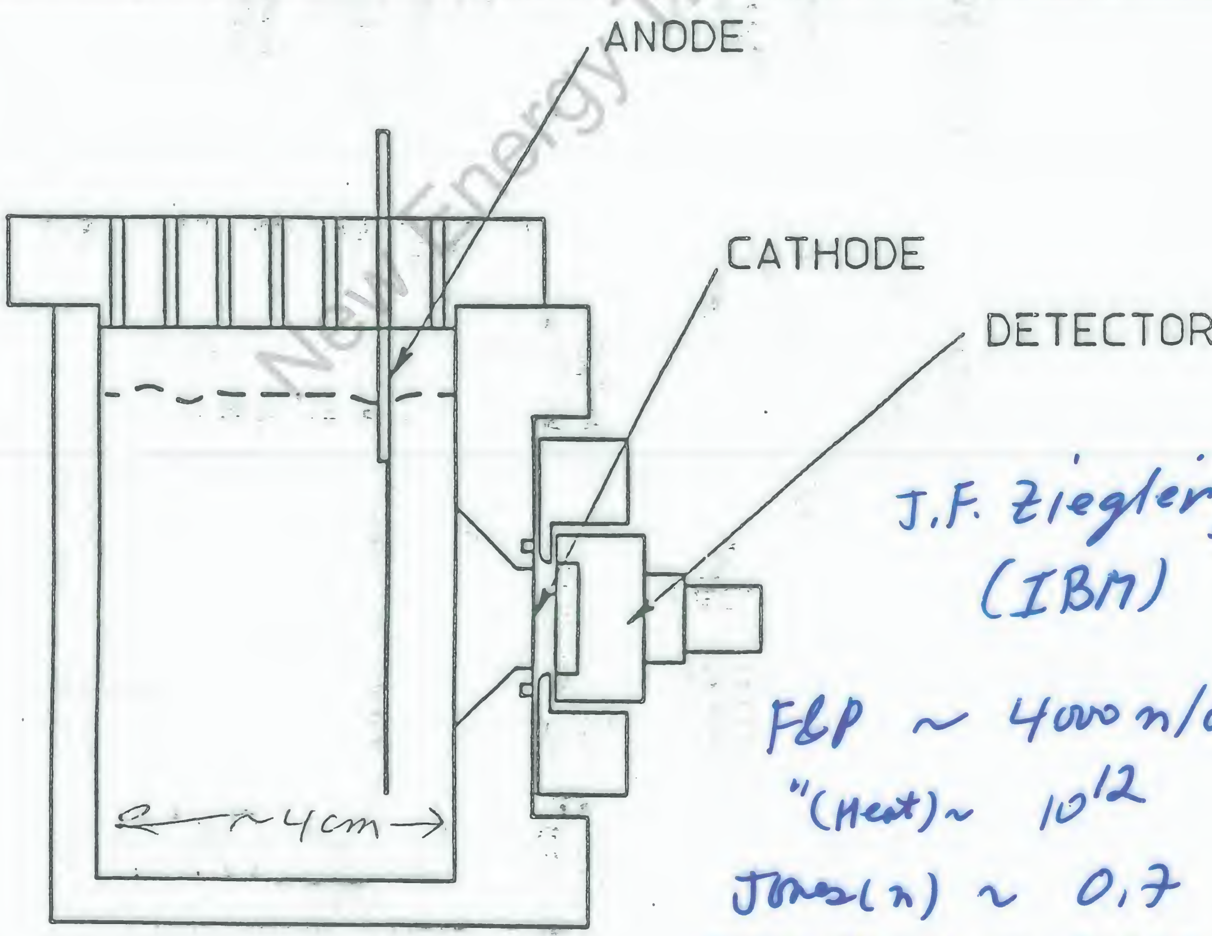

COUNTS
50
40
30
20
10
0
1
6
11
16
21
26
31
36
41
46
51
56
61
ELAPSED TIME (~~min~~) hours


60 μsec



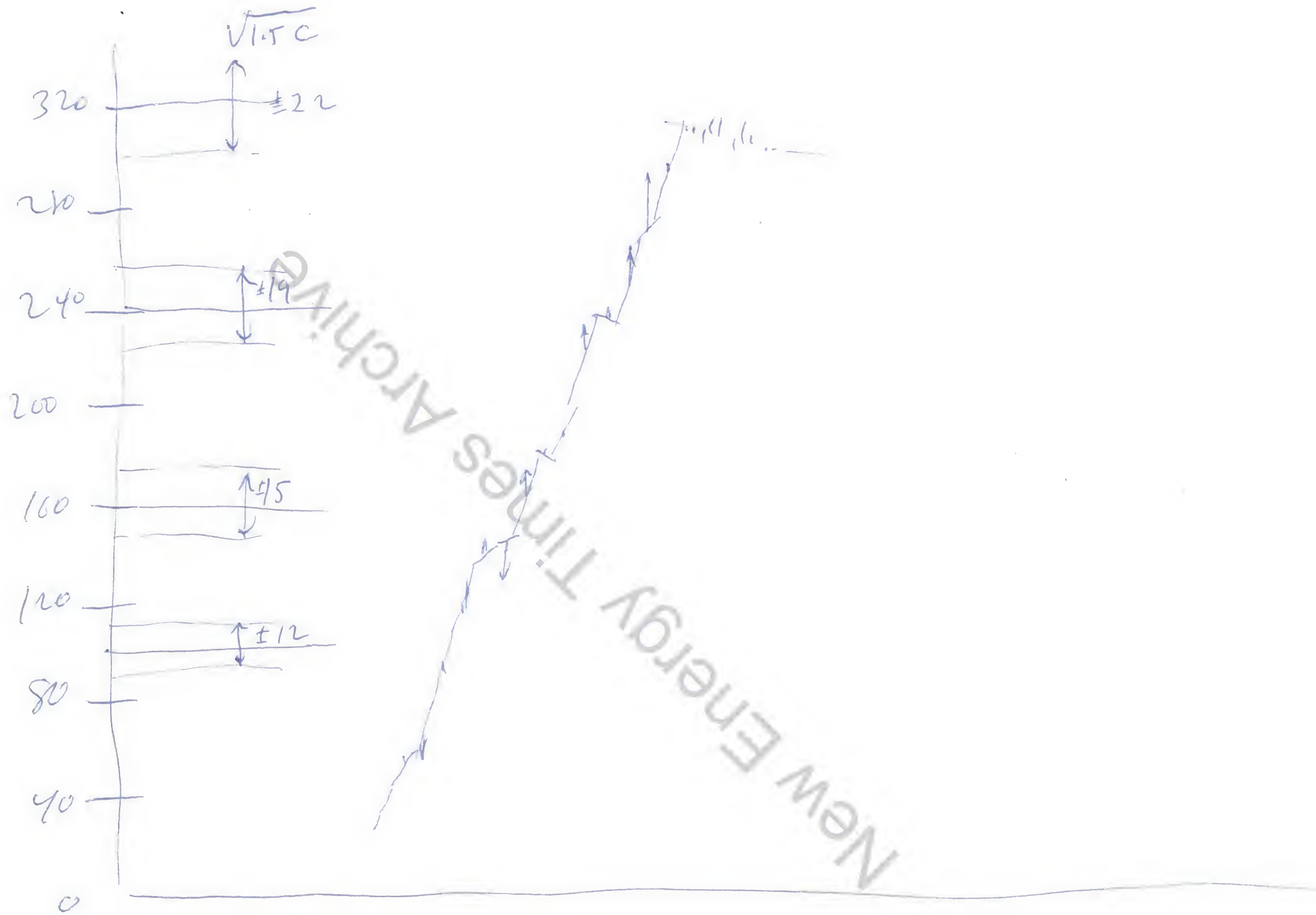
50
COUNTS
40
30
20
10
0
1
6
11
16
21
26
31
36
41
46
51
56
61
ELAPSED TIME ~~(min)~~ hours

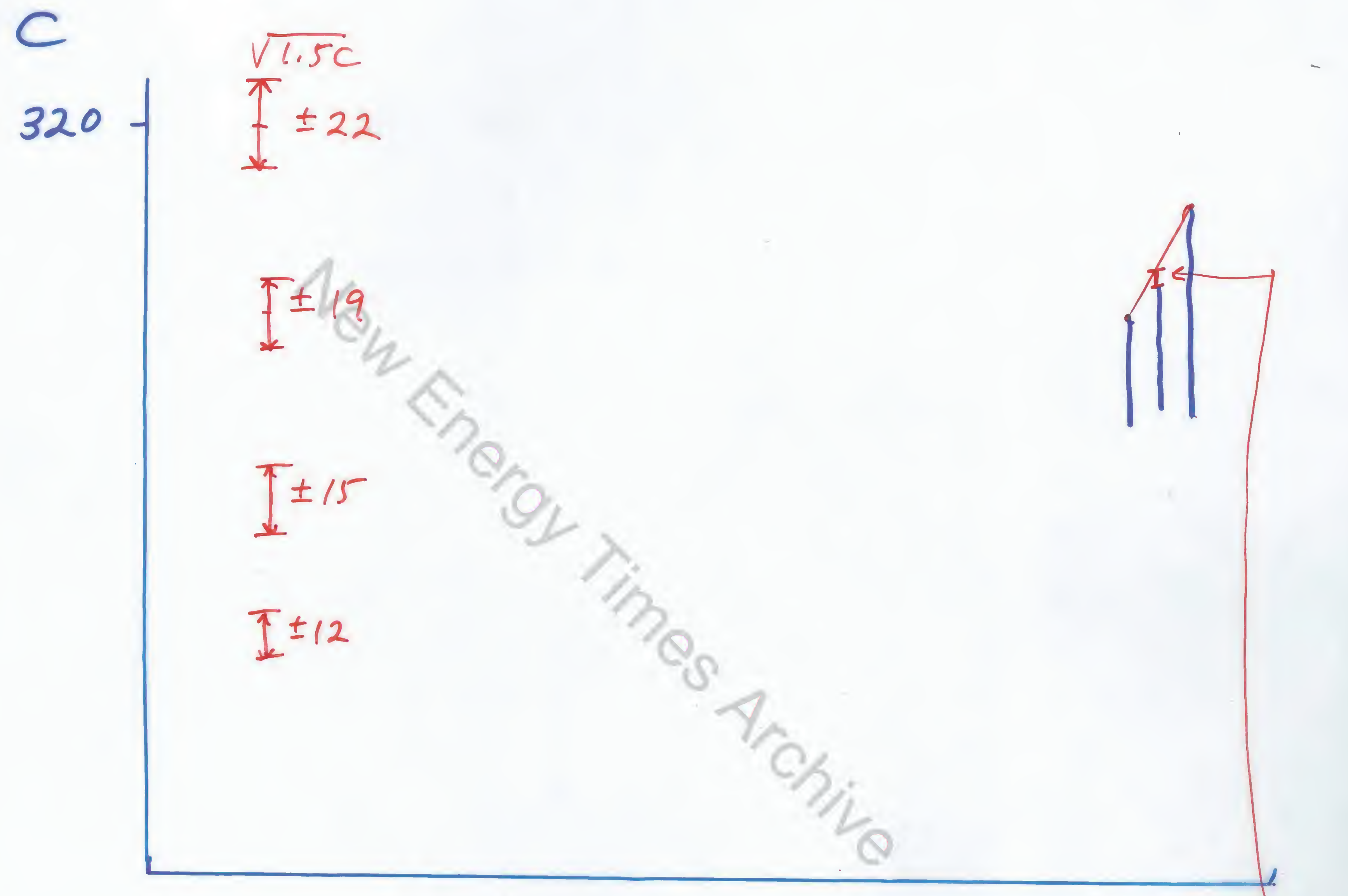




J.F. Ziegler, et al
(IBM)

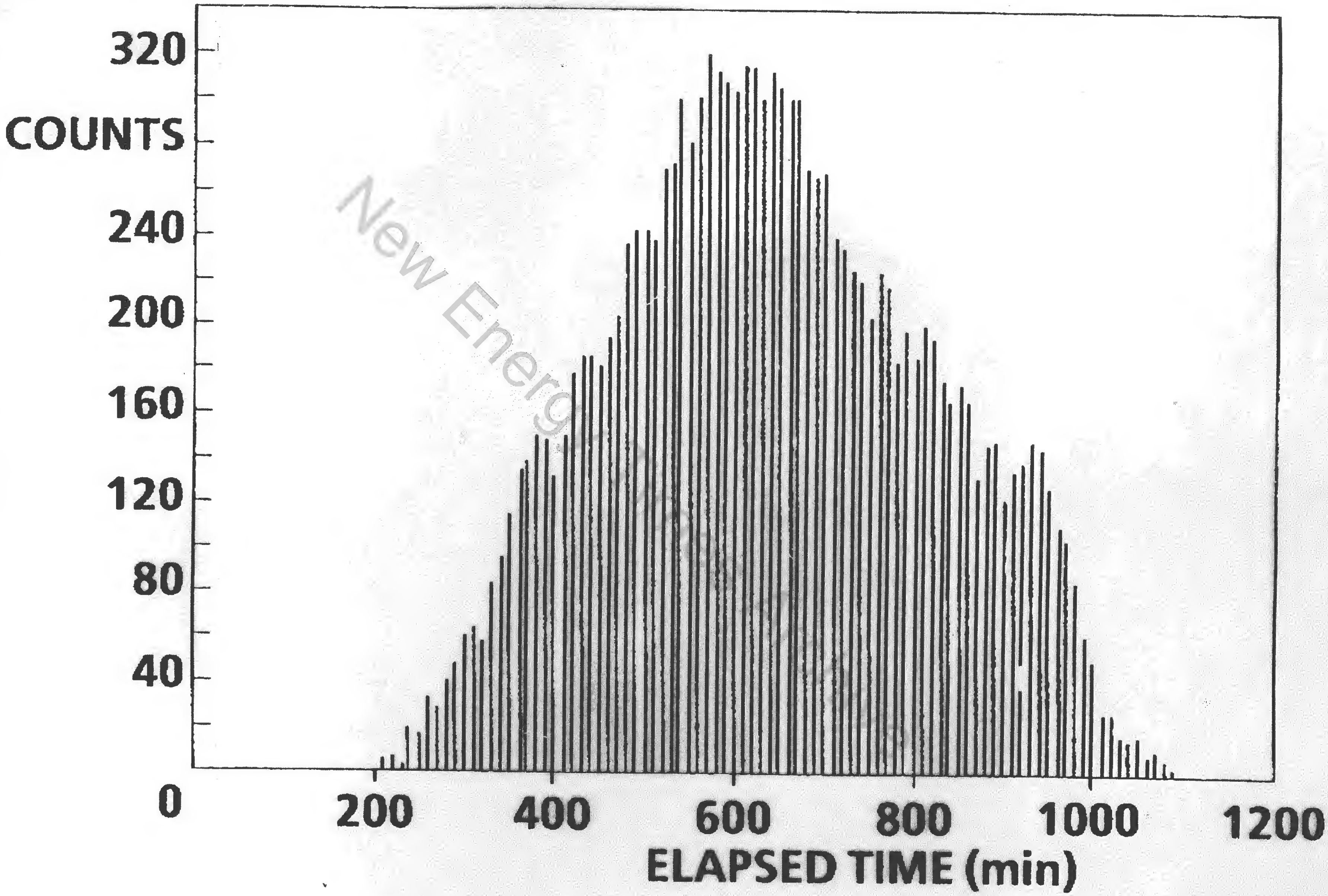
F&P ~ 4000 n/cm³-s
" (Heat) ~ 10^{12}
Jones (n) ~ 0.7
IBM (t,p) ≤ 0.005 /cm³-s


$\sqrt{1.5C}$
±22
±19
±15
±12
320
280
240
200
160
120
80
40
0



standard deviation of a single point should be $C^{1/2}$

S.D. of a point from the <u>average</u> of adjacent points should be $\sqrt{1.5C}$



320
COUNTS
240
200
160
120
80
40
0
200
400
600
800
1000
1200
ELAPSED TIME (min)

TABLE 1. Generation of excess enthalpy in Pd-cathodes as a function of current density and electrode size.

electrode type	dimensions	current density /mA cm^{-2}	excess rate of heating / watt cm^{-3}	excess specific rate of heating/watt cm^{-3}	current density /mA cm^{-2}	excess rate of Heating/watt	excess specific rate of Heating/watt cm^{-3}	current density * /mA cm^{-2}	excess rate of * Heating/watt	excess specific rate of Heating/watt cm^{-3}
Rods	0.1x10cm	8	.0075	.095	64	.079	1.01	512	.654	8.33
	0.2x10cm	8	.036	.115	64	.493	1.57	512	3.02	9.61
	0.4x10cm	8	.153	.122	64	1.751	1.39	512	26.8	21.4
Sheet	0.2x8x8cm	0.8	.153	0.[illegible]	1.2	.027	.0021	1.6	.079	.0061
Cube	1x1x1cm	125	WARNING! IGNITION? see text*		250					

*Measured on electrodes of length 1.25cm and rescaled to 10cm.

.103
04/12/89

TABLE 2. Generation of excess enthalpy in Pd rod cathodes expressed as a percentage of breakeven values.

electrode type	dimensions	current density /mA cm^{-2}	excess heating* /% of breakeven	excess heating** /% of breakeven	excess heating*** /% of breakeven	current density /mA cm^{-2}	excess heating* /% of breakeven	excess heating** /% of breakeven	excess heating*** /% of breakeven	current density /mA cm^{-2}	excess heating* /% of breakeven	excess heating** /% of breakeven	excess heating*** /% of breakeven
Rods	0.1x10cm	8	23	12	60	64	19	11	79	512	5	5	81
	0.2x10cm	8	62	27	286	64	46	29	247	512	14	11	189
	0.4x10cm	8	111	53	1224	64	66	45	438	512	59	48	839

* % of breakeven based on Joule heat supplied to cell and anode reaction $4OD^- \rightarrow 2D_2O + O_2 + 4e$

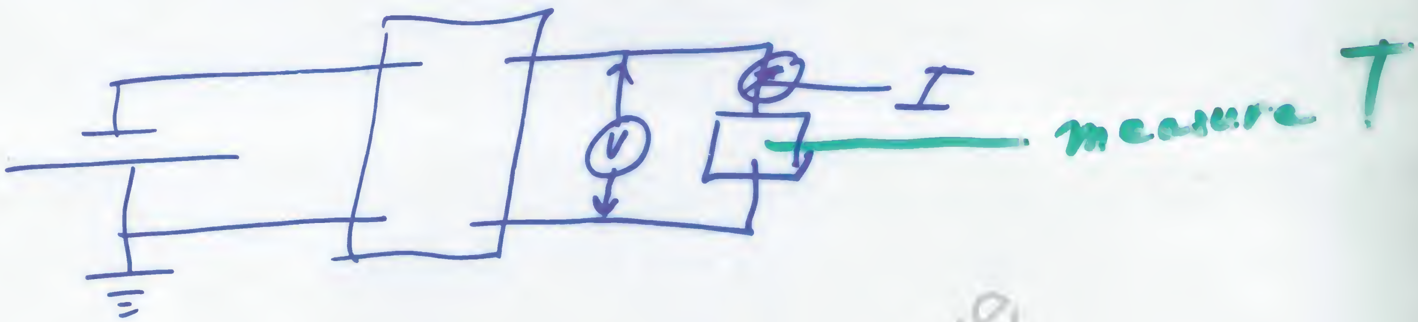
** % of breakeven based on total energy supplied to cell and anode reaction $4OD^- \rightarrow 2D_2O + O_2 + 4e$

*** % of breakeven based on total energy supplied to cell and for an electrode reaction $D_2 + 2OD^- \rightarrow 2D_2O + 4e$ with a cell potential of 0.5V.

05/12/89

[1]

Not even so easy to calculate "power in"!



I have put in $I = 0.1$ A

$V = 200$ V

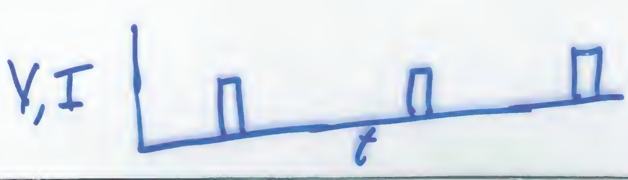
and dissipated 200W $\gg V \times I$

$$\overline{P} = \langle V(t) \cdot I(t) \rangle$$

<u>If</u> V is constant $\quad \overline{P} = V \langle I(t) \rangle$

If I is constant $\quad \overline{P} = \langle V(t) \rangle I$

But if not, $\quad \overline{P} \neq \langle V(t) \rangle \times \langle I(t) \rangle$



R. L. Garwin